

We claim:

- 1       1.     An interconnect structure formed on a substrate, the structure comprising:  
2                 a dielectric layer overlying the substrate, said dielectric layer being  
3                 formed of a carbon-containing dielectric material having a dielectric constant  
4                 of less than about 4;  
5                 a continuous hardmask layer on said dielectric layer, said hardmask  
6                 layer having a top surface;  
7                 at least one conductor embedded in said dielectric layer and having a  
8                 surface coplanar with the top surface of said hardmask layer; and  
9                 a cap layer on said at least one conductor and on said hardmask layer,  
10                said cap layer having a bottom surface in strong adhesive contact with said  
11                conductor, wherein said cap layer is formed of silicon nitride by a plasma-  
12                enhanced chemical vapor deposition (PE CVD) process.
  
- 1       2.     The interconnect structure according to Claim 1, further comprising a pre-clean  
2                layer disposed beneath said cap layer and on said at least one conductor and  
3                said hardmask layer, said pre-clean layer being formed of a material  
4                comprising copper, silicon and oxygen.
  
- 1       3.     The interconnect structure according to Claim 1, further comprising a  
2                conductive liner disposed between said conductor and said dielectric layer.
  
- 1       4.     The interconnect structure according to Claim 1, further comprising an  
2                adhesion promoter layer disposed between said dielectric layer and the  
3                substrate.

- 1 5. The interconnect structure according to Claim 1, wherein said dielectric layer is  
2 formed of an organic thermoset polymer having a dielectric constant of about  
3 1.8 to about 3.5.
- 1 6. The interconnect structure according to Claim 5, wherein said dielectric layer is  
2 formed of a polyarylene ether polymer.
- 1 7. The interconnect structure according to Claim 1, wherein said hardmask layer  
2 is formed of silicon nitride.
- 1 8. The interconnect structure according to Claim 1, wherein said hardmask layer is  
2 formed of silicon carbide.
- 1 9. The interconnect structure according to Claim 1, wherein said conductor is  
2 formed of copper.
- 1 10. The interconnect structure according to Claim 1, wherein said hardmask layer  
2 has a thickness of at least about 500 angstroms.
- 1 11. The interconnect structure according to Claim 7, wherein said hardmask layer  
2 has a thickness of at least about 25 angstroms.
- 1 12. The interconnect structure according to Claim 8, wherein said hardmask layer  
2 has a thickness of at least about 100 angstroms.
- 1 13. The interconnect structure according to Claim 1, wherein said cap layer has a  
2 thickness of about 5 to about 120 nm.

1 14. The interconnect structure according to Claim 1, wherein said cap layer has a  
2 composition of about 30 to 45 atomic % silicon, about 30 to 55 atomic %  
3 nitrogen, and about 10 to 25 atomic % hydrogen.

1 15. A method for forming an interconnect structure on a substrate, the method  
2 comprising the steps of:  
3 depositing a dielectric layer, said dielectric layer being formed of a  
4 carbon-containing dielectric material having a dielectric constant of less than  
5 about 4;  
6 depositing a hardmask layer on said dielectric layer, said hardmask  
7 layer having a top surface;  
8 forming an opening in said dielectric layer and said hardmask layer;  
9 filling said opening with a conductive material, thereby forming a  
10 conductor, said conductor having a surface coplanar with the top surface of  
11 said hardmask layer;  
12 exposing said conductor to a reducing plasma comprising at least one  
13 gas selected from the group consisting of H<sub>2</sub>, N<sub>2</sub>, NH<sub>3</sub> and noble gases; and  
14 depositing silicon nitride on said conductor by a plasma-enhanced  
15 chemical vapor deposition (PE CVD) process, thereby forming a silicon nitride  
16 cap layer.

1 16. The method according to Claim 15, wherein said hardmask layer is formed of  
2 silicon nitride, and is deposited by a chemical vapor deposition (CVD) process.

1 17. The method according to Claim 15, wherein said hardmask layer is formed of  
2 silicon carbide, and is deposited by a chemical vapor deposition (CVD)  
3 process.

- 1 18. The method according to Claim 15, wherein said conductor is exposed to a  
2 reducing plasma comprising  $\text{NH}_3$  at a flow rate of at least about 4000 sccm.
- 1 19. The method according to Claim 15, wherein said conductor is exposed to a  
2 reducing plasma with a high frequency RF power of about 150 watts to about  
3 450 watts and a low frequency RF power of about 100 watts to about 300  
4 watts.
- 1 20. The method according to Claim 15, wherein said conductor is exposed to a  
2 reducing plasma in a chemical vapor deposition (CVD) reactor at a pressure of  
3 less than about 20 torr, and said silicon nitride cap layer is deposited in the  
4 same CVD reactor at a pressure of less than about 10 torr.